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Original Article

Mercury Exposure among Garbage Workers in Southern Thailand

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Objectives: 1) To determine mercury levels in urine samples from garbage workers in Southern Thailand, and 2) to describe the association between work characteristics, work positions, behavioral factors, and acute symptoms; and levels of mercury in urine samples.
Methods: A case-control study was conducted by interviewing 60 workers in 5 hazardous-waste-management factories, and 60 matched non-exposed persons living in the same area of Southern Thailand. Urine samples were collected to determine mercury levels by cold-vapor atomic absorption spectrometer mercury analyzer.
Results: The hazardous-waste workers' urinary mercury levels (10.07 μg/g creatinine) were significantly higher than the control group (1.33 μg/g creatinine) ($p < 0.001$). Work position, duration of work, personal protective equipment (PPE), and personal hygiene, were significantly associated with urinary mercury level ($p < 0.001$). The workers developed acute symptoms - of headaches, nausea, chest tightness, fatigue, and loss of consciousness at least once a week - and those who developed symptoms had significantly higher urinary mercury levels than those who did not, at $p < 0.05$. A multiple regression model was constructed. Significant predictors of urinary mercury levels included hours worked per day, days worked per week, duration of work (years), work position, use of PPE (mask, trousers, and gloves), and personal hygiene behavior (ate snacks or drank water at work, washed hands before lunch, and washed hands after work).
Conclusion: Changing garbage workers' hygiene habits can reduce urinary mercury levels. Personal hygiene is important, and should be stressed in education programs. Employers should institute engineering controls to reduce urinary mercury levels among garbage workers.

Key Words: Hazardous waste, Garbage workers, Urinary mercury

Introduction

Waste is transferred to municipal waste-collection centers, where it is collected by area municipalities for relegation to landfills and dumps. However, waste reduction is, where possible, the top priority. The other priorities, in descending order, are reuse, recycling, energy generation, and disposal [1]. Hazardous-waste-management factories are an important economic activity in rapidly developing countries like Thailand, where, for example, 616.5 tons of hazardous waste have been the source of environmental problems [2]. Although hazardous waste is a major source of mercury exposure, the release of this metal from consumer products and devices - electrical switches, fluorescent lights, and batteries - can also contribute to public exposure [3,4]. This type of pollution is transmitted via these media, and will impact, directly or indirectly, upon humans and the natural environment: the biota, air, soil, and water [5].

Hazardous-waste-management factories in Southern Thailand are generally small, with less than 10 workers. The

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process involves 4 main activities: (1) receiving the solid waste, (2) separating the hazardous waste from the solid waste, (3) compacting the hazardous waste, and (4) transferring the hazardous waste to a central disposal facility. Garbage workers and workers in hazardous-waste-management factories are at risk of exposure to mercury and other heavy metals [6]. The high-risk stages of the process include exposure to mercury while separating the hazardous waste from the solid waste. Mercury contamination and poisoning of workers has been reported in other industries [7]. Mercury exposure is, therefore, associated with a range of adverse health effects for all body systems. In particular, mercury is associated with kidney disease, respiratory diseases, cardiovascular damage, blood effects, and neurotoxicity [8-11].

Several reports have indicated that waste sorting and recycling are associated with occupational health problems, such as pulmonary diseases, gastrointestinal symptoms, mucous-membrane and skin problems, and musculoskeletal disorders [12,13]. Thus, the potential health effects from hazardous waste are a concern to garbage workers working on these sites. The objectives of this study were to determine and evaluate the level of urinary mercury among workers exposed to mercury from hazardous waste in Southern Thailand, and to describe worker behaviors and acute symptoms, and evaluate them in terms of their possible role in worker contamination and transfer of mercury to the body.

Materials and Methods

In this case-control study, urinary mercury samples were collected from workers in 5 hazardous-waste-management factories in Southern Thailand, in September-November 2011. This research was approved by the Ethics Committee of the Institute of Research and Development, Thaksin University.

Study population and samples

The study population comprised garbage workers and workers who worked in hazardous-waste-management factories in Southern Thailand. This study enrolled workers at waste sites with records of higher exposures; and 60 workers were recruited from 5 factories in Southern Thailand. The inclusion criteria for the exposed group were: garbage workers and workers aged 20-60 years, in occupational contact with hazardous waste and who had worked with that occupational contact for at least one year. They agreed to participate in the study, and provided written informed consent. Of the 60 exposed subjects recruited into the study, 53 were male and 7 female. The non-exposed group (60 persons) was selected from the general population living in the same area as the factories, and comprised people who did not have occupational contact with hazardous waste or mercury. They were matched for age and sex with the exposed group.

Sample collection

The 120 subjects (60 exposed; 60 non-exposed) were interviewed using a questionnaire. General information on the garbage workers was collected by face-to-face interview using a survey form, and by walk-through survey and on-site. Spot urine samples (30 mL) were collected from the first urination in the morning.

Questionnaire

In the questionnaire, information on the following variables was collected: general information, work characteristics (e.g., office workers, cleaners, drivers, garbage workers), personal hygiene, and the development of acute symptoms. Acute symptoms were short-term mercury post-exposure symptoms, as a result of managing hazardous waste processes, which lasted 7 days. Direct observation was also used to confirm the interview results.

Urine collection

Spot urine samples (30 mL) were collected from first urination in the morning, then kept in polypropylene sample vessels and stored at -20^{o}C for analysis. At the end of each shift, the subjects were also interviewed about their general characteristics, including work-related factors.

Laboratory analysis

Determination of creatinine in urine

Creatinine in urine was measured using a test kit (Merckotest no 3385; Merck, Darmstadt, Germany), based on the Jaffé reaction.

Mercury measurement

Two milliliters of each urine sample were mixed with 0.1 mL of 35% w/w nitric acid, 0.2 mL of 50% w/w sulfuric acid and 0.5 mL of 5% w/v potassium permanganate, then the samples were submitted to microwave digestion at an elevated temperature for 15 minutes. The sample solution was allowed to stand at room temperature. If the solution's color changed from purple to brown, then a further 0.5 mL of permanganate solution was added, mixed, and allowed to stand for 15 minutes. This process, of adding successive aliquots of permanganate solution and allowing the reaction to proceed, was maintained until the purple color was sustained. With increasing masses of dissolved organic materials, increasing volumes of permanga-

nate solution were required. After the permanganate reaction was complete, 0.4 mL of 2.5% (w/v) potassium persulfate were added and mixed. Incubation was conducted at 95°C for at least 2 hours, and then left to cool. Five percent (w/v) hydroxylamine hydrochloride (0.5 mL) and 1 mL of 10% $SnCl_2$ solution were added with an accessory dispenser. The total volume was made up to 10.0 mL with reagent water, and mixed well prior to determination. This method of urinary mercury determination was modified from that of Ham (1997) [14].

Validation of the analyses

Urine mercury was analyzed by CETAC M6000A cold-vapor atomic absorption spectrometer (CVAAS M6000A; CETAC, Omaha, NE, USA) mercury analyzer. Field water blank samples (10% of urine specimens) were frozen and shipped on dry ice in all of the analyses as a quality control. These field blanks were analyzed for mercury using the same method. Determination of urinary-mercury level was calibrated by preparing a series of standard additions to contain 0, 10, 20, and 40 μg/dL. The correlation coefficient (r) between the mercury concentration in the authentic mercury solution and absorption was 0.9998. The overall limit of detection was 5 μg/g creatinine. External quality control (BIO-RAD Lyphochek® Urine Metals Control; Bio-Rad, Hercules, CA, USA) and a 5 μg/L calibration range standard check were analyzed at the start and end of analysis, and after every 10 samples. The accuracy of the overall method ranged between 97.1 and 99.9%, and the calculated precision was within 5% relative standard deviation (RSD). The urine samples were analyzed at the laboratory of the Faculty of Medicine Technology, Mahidol University.

Statistical analysis

Descriptive statistics were used to present the urinary-mercury test results. The independent t-test was used to compare the means of continuous variables, between the exposed and control groups. Normally distributed data group means were compared using a Student's t-test or ANOVA for 2 or more than 2 group, respectively. Multiple linear regression analysis was used to evaluate the effects on urinary-mercury levels of the general characteristics, work characteristics, occupational lifestyle, personal protective equipment (PPE), and personal hygiene, of workers. Used PPE and personal hygienic practice were treated as dummy variables (yes/no and always/sometimes) in the model. A p-value < 0.05 was considered statistically significant.

Table 1. General characteristics of the subjects

Parameter	Control subjects (n = 60)	Exposed subjects (n = 60)
Gender		
Male	53 (88.3)	53 (88.3)
Female	7 (11.7)	7 (11.7)
Age (year)		
20-30	36 (60.0)	36 (60.0)
31-40	18 (30.0)	18 (30.0)
41-50	6 (10.0)	6 (10.0)
Education level		
Primary school	5 (8.3)	14 (23.3)
Secondary school	27 (45.0)	22 (36.7)
Vocational school	21 (35.0)	11 (18.3)
Diploma or equivalent	2 (3.4)	10 (16.7)
Bachelor degree or higher	5 (8.3)	3 (5.0)
Marital status		
Single	32 (53.3)	45 (75.0)
Married	15 (25.0)	10 (16.7)
Widowed	5 (8.3)	2 (3.3)
Separated/divorced	8 (13.4)	3 (5.0)
Income (US dollars)		
≤ 500	34 (56.7)	19 (31.7)
> 500	26 (43.3)	41 (68.3)
Smoke cigarettes		
Yes	28 (46.7)	36 (60.0)
No	32 (53.3)	24 (40.0)
Consume alcohol		
Yes	25 (41.7)	35 (58.3)
No	35 (58.3)	25 (41.7)
Consume seafood per month		
Once or twice a month	32 (53.3)	31 (51.7)
≤ 5	22 (36.7)	20 (33.3)
> 5	6 (10.0)	9 (15.0)

Values are presented as number (%).

Results

General characteristics of the subjects

One hundred and twenty subjects participated in the present study. Most subjects (60.0%) were aged between 20-30 years. All subjects were Buddhists. Most of the exposed subjects had secondary and primary education levels, while the control subjects had secondary and vocational education levels. More exposed subjects smoked cigarettes and drank alcoholic beverages than did control subjects (Table 1).

Work characteristics

Half of the subjects had been working for < 5 years. Most subjects worked for > 8 hours per day and 5 days per week, at 55.0 and 51.7%, respectively. Most subjects (43.3%) sorted hazardous waste from general waste (Table 2).

Urinary mercury levels of the subjects

The median urinary mercury levels of the exposed and control subjects were significantly different, at $p < 0.001$ (Table 3). The urinary mercury levels of the workers were below the 35 μg/g creatinine biological exposure index recommended by the American Conference of Governmental Industrial Hygiene (ACGIH) [15].

Table 2. Work characteristics of the subjects

Parameter	Exposed subjects (n = 60)
Duration of work (year)	
≤ 5	30 (50.0)
> 5	30 (50.0)
Hours work per day	
≤ 8	27 (45.0)
> 8	33 (55.0)
Day work per week	
≤ 5	29 (48.3)
> 5	31 (51.7)
Position	
Office worker (indoors)	11 (18.3)
Cleaner (indoors)	10 (16.7)
Driver (outdoors)	13 (21.7)
Garbage worker (outdoors)	26 (43.3)

Values are presented as number (%).

General characteristics and urinary mercury levels

General characteristics - of gender, age, education level, income, cigarette smoking, or alcohol consumption - and their relation to urinary mercury levels, were not significantly statistically different between the two groups.

Working environments of garbage workers and urinary mercury levels

From observation and walk-through survey, 51.7% of garbage workers worked in factories with > 500 kg/day of hazardous waste, and 48.3% in factories with < 500 kg/day. Garbage workers in factories with > 500 kg/day of hazardous waste had significantly higher urinary mercury levels than those who worked in factories with ≤ 500 kg/day. For those working in hazardous-waste factories, those who worked and used the same places during their work breaks had significantly higher urinary mercury levels than those who did not (use the same places). In the process of separating hazardous waste, the garbage workers who had mechanical assistance had significantly lower urinary mercury levels than those who did not. Different types of ventilation system showed significant differences in reducing the urinary mercury levels of garbage workers.

Occupational lifestyles, PPE, personal hygiene of workers, and urinary mercury levels

Most workers (65.0%) worked > 8 hours per day, and 81.7% worked 7 days per week. The majority (90.0%) started working at age < 12 years. 18.3% worked in an office, 16.7% were cleaners, 21.7% drivers, and 43.3% garbage workers. Most workers (53.3%) did not use a cotton mask to protect themselves from dust and fumes, and 20.0% of workers used gloves when collecting or handling hazardous waste. Fifty-one percent sometimes ate snacks or drank water while working. Over half of the workers (53.3%) always washed their hands before lunch. Most workers (75.0%) always washed their hands after work, and 23.3% sometimes washed their clothes. Before going home, none of the workers took a shower or regularly changed

Table 3. Comparison of urinary mercury levels in exposed and control subjects

Metal	Control subject (n = 60)	Exposed workers (n = 60)	p-value
Mercury (median, μg/g creatinine)	1.33	10.07	<0.001*
Interquartile range	2.08	11.58	

*Significant at < 0.05.

Table 4. Variables related to garbage workers' urinary mercury levels (n = 60)

Characteristic	Workers	Urinary mercury levels (μg/g creatinine)	p-value
General characteristic			
Gender			
Male	53	9.64 ± 7.05	0.116
Female	7	13.31 ± 8.09	
Age (year)			
20-30	36	9.34 ± 7.07	0.491
> 30-40	18	11.18 ± 7.77	
> 40-50	6	11.12 ± 6.89	
Education level			
Primary school	14	8.03 ± 6.38	0.907
Secondary school	22	9.13 ± 8.18	
Vocational school	11	12.34 ± 8.10	
Diploma or equivalent	10	10.51 ± 4.89	
Bachelor degree or higher	3	15.70 ± 1.85	
Income (US dollars)			
≤ 100	19	8.32 ± 7.98	0.556
> 100	41	10.88 ± 6.76	
Smoke cigarettes			
Yes	36	9.16 ± 7.70	0.093
No	24	11.44 ± 6.29	
Consume alcohol			
Yes	35	9.14 ± 6.64	0.079
No	25	11.38 ± 7.87	
Consume seafood per month			
Once or twice a month	32	10.50 ± 7.18	0.300
≤ 5	22	15.31 ± 9.25	
> 5	6	17.23 ± 6.48	
Working environment of garbage workers			
Weight of hazardous waste (kg/day)			
≤ 500	31	5.02 ± 3.90	< 0.001*
> 500	29	15.48 ± 5.82	
Working and living in the same area			
Yes	26	15.76 ± 4.54	< 0.001*
No	34	5.72 ± 2.03	

Table 4. Continued

Characteristic	Workers	Urinary mercury levels (μg/g creatinine)	p-value
Process in separating hazardous waste			
Used machine and human combined	44	7.03 ± 5.10	< 0.001*
Used human only	16	18.44 ± 5.24	
Ventilation systems used			
Natural ventilation	26	16.47 ± 5.15	< 0.001*
Electric fan	13	4.70 ± 2.16	
Combined natural ventilation and electric fan	21	5.47 ± 2.89	
Occupational lifestyles			
Duration of work (year)			
> 5	30	15.95 ± 4.99	0.011*
≤ 5	30	4.19 ± 3.01	
Hours worked per day			
> 8	33	14.32 ± 5.90	0.002*
≤ 8	27	4.88 ± 4.98	
Days worked per week			
> 5	31	14.81 ± 5.89	0.058
≤ 5	29	9.33 ± 4.93	
Position			
Office worker (indoors)	11	2.17 ± 0.73	<0.001*
Cleaner (indoors)	10	3.76 ± 1.82	
Driver (outdoors)	13	8.66 ± 3.92	
Garbage worker (outdoors)	26	16.54 ± 5.05	
Personal protective equipment			
Mask			
Yes	32	4.53 ± 3.15	<0.001*
No	28	16.41 ± 4.88	
Gloves			
Yes	48	7.77 ± 5.48	<0.001*
No	12	19.28 ± 5.56	
Personal hygiene of workers			
Ate snacks or drank water at work			
Always	29	16.14 ± 4.94	<0.001*
Sometimes	31	4.39 ± 3.22	
Washed hands before lunch			
Always	32	14.72 ± 3.69	0.425
Sometimes	28	16.19 ± 4.99	
Washed hands after work			
Always	45	6.96 ± 4.75	<0.001*
Sometimes	15	19.36 ± 4.96	

Values are presented as number or mean ± standard deviation.
*Significant at $p < 0.052$.

their clothes. It was found that mean urinary mercury levels and duration of work, hours worked per day, days worked per week, work position, use of PPE (mask, gloves, and trousers), eating snacks or drinking water during work, washing hands before lunch, and washing hands after work, were significantly different, at $p < 0.05$ (Table 4). Workers who had worked > 5 years had significantly higher urinary mercury levels than those who had worked < 5 years ($p < 0.001$). Workers who had worked ≥ 8 hours per day and 5 days per week had significantly higher urinary mercury levels than those who had worked < 8 hours per day and 5 days per week ($p = 0.002$ and $p < 0.001$, respectively). The results indicated that the median urinary mercury levels among work positions were significantly different ($p < 0.001$). Workers who used mask and/or gloves had significantly lower urinary mercury levels than those who did not. Workers who always ate snacks had significantly higher urinary mercury levels than those who sometimes ate them. Workers who always washed their hands after work had significantly lower urinary mercury levels than those who sometimes did so.

To predict the urinary mercury levels of garbage workers, a multiple regression model was constructed, as shown in Table 5. Significant predictors of urinary mercury levels included hours worked per day, days worked per week, duration of work (years), work position, use of PPE (mask, trousers, and gloves), and personal hygiene behavior (ate snacks or drank water at work, washed hands before lunch, and washed hands after work). Workers who had worked > 5 years had significantly higher urinary-mercury levels than those had worked < 5 years ($p = 0.011$). Garbage workers had higher urinary-mercury levels than position workers ($p < 0.001$). Workers who used both mask and gloves ($r = -0.0458$ and $r = -0.0369$, respectively) had significantly lower urinary-mercury levels than those who did not ($p < 0.001$). Workers who always ate snacks had significantly higher urinary-mercury levels than those who sometimes did so ($p < 0.001$). Worker who always washed hands after work had significantly lower urinary-mercury levels than those who sometimes did so ($p < 0.001$). Hours worked per day, days worked per week, duration of work (years), and work position were positively associated with urinary-mercury levels.

Acute symptoms and urinary mercury levels

Most non-exposed subjects reported no acute symptoms. Among the exposed subjects, 36.7% reported headache, 28.3% nausea, 10.0% chest tightness, 18.3% fatigue, and 23.3% loss of consciousness, respectively. The urinary-mercury levels of subjects who reported, and who did not report, acute symptoms were compared. The exposed workers who reported headache, rash, chest tightness, fatigue, and loss of consciousness had significantly higher urinary mercury levels than those did not do so ($p = 0.004$, < 0.001, < 0.001, < 0.001, and < 0.001, respectively) (Table 6).

Discussion

Urinary mercury levels

Urinary mercury level is commonly used as an indicator and diagnostic measure for mercury exposure in humans [15]. The results of the present study showed that the urinary mercury levels in these workers were higher than those in the matched

Table 5. Multiple regression occupational life style, used PPE, and personal hygiene behavior on urinary mercury levels in garbage workers

Parameter	Regression coefficient	Standard error	p-value
Hours worked per day (more than 8 hours vs. less than 8 hours)	0.0004	0.0003	0.0658
Days worked per week (more than 5 days vs. less than 5 days)	0.1455	0.0219	0.0547
Duration of work (more than 5 years vs. less than 5 years)	0.0024	0.0010	0.0113*
Position (garbage workers vs. others)	0.0034	0.0020	0.0217*
Mask (yes vs. no)	-0.0458	0.0113	0.0001*
Gloves (yes vs. no)	-0.0369	0.0145	0.0001*
Ate snacks or drank water at work (always vs. sometimes)	0.0585	0.0194	0.0001*
Washed hands before lunch (always vs. sometimes)	-0.0289	0.0269	0.2678
Washed hands after work (always vs. sometimes)	-0.0462	0.0123	0.0001*

PPE: personal protective equipment.
*Significant at $p < 0.05$.

Table 6. Acute symptoms related to garbage workers' urinary mercury levels (n = 60)

Acute symptom	Workers exposed to mercury	Urinary mercury levels (μg/g creatinine)	p-value
Headache			
No	38	5.87 ± 4.25	0.004*
Yes	22	17.35 ± 5.11	
Nausea			
No	43	8.69 ± 6.87	0.710
Yes	17	13.57 ± 7.01	
Rash			
No	37	6.08 ± 4.66	<0.001*
Yes	23	16.49 ± 5.81	
Chest tightness			
No	54	8.72 ± 5.86	<0.001*
Yes	6	22.28 ± 7.04	
Fatigue			
No	49	8.06 ± 5.83	<0.001*
Yes	11	19.03 ± 5.91	
Loss of consciousness			
No	46	7.47 ± 5.72	<0.001*
Yes	14	18.61 ± 4.41	

*Significant at $p < 0.05$.

control subjects. Among workers in the present study, the median urinary mercury levels were 10.07 (range 1.2-29.1 μg/g creatinine). All workers had urinary mercury levels of < 35 μg/g creatinine [15], the ACGIH-recommended biological exposure index for mercury in urine.

Factors associated with urinary mercury levels

A recent study found that many factors influence increased urinary mercury levels. Garbage workers had higher urinary mercury levels than office workers, cleaners, and drivers. Although most garbage workers worked outside an office, all garbage workers brought them into continuous contact with mercury, which is reflected in the higher urinary-mercury levels among the garbage workers than the other positions. Garbage workers were at greater risk of exposure to mercury than were other positions. The result of the present study was similar to that of Decharat et al. [7], in which the urinary mercury levels of Thai nielloware workers differed by job type.

With regard to working duration, it was found that median urinary mercury levels differed significantly; workers who had worked ≥ 5 years had significantly higher urinary mercury levels than those who had worked < 5 years. In addition, for hours worked per day and days worked per week, median urinary mercury levels differed significantly; workers who worked ≥ 8 hours per day and worked ≥ 5 days per week (0.0004 and 0.1455, respectively), had significantly higher urinary mercury levels than those who worked < 8 hours per day and < 5 days per week, respectively. This may be due to workers' long-term exposure to mercury, leading to its accumulation in their bodies, due to the lack of appropriate prevention measures [16]. Therefore, comparing the results related to years of activity, urinary mercury levels are slightly higher. It should be noted that, besides the years of work-place exposure, other important factors influence urinary mercury levels in the human body, such as hours worked, and frequency of contact with hazardous waste [17-19]. Garbage workers were considered informal workers; some used their work areas during their breaks. Therefore, owners should provide a separate eating, drinking and smoking area, and provide bathing and laundry facilities. The use of PPE at work can help prevent contamination.

Workers who used masks and gloves had significantly lower urinary mercury levels than those who did not [20]. The present study agrees with Rogers [21], who reported that the risk of exposure to hazardous materials will decrease if the appropriate behaviors are adopted and practiced. However, the types of PPE in use in these factories were inappropriate for field work. Mercury can accumulate on the surfaces of PPE used by the garbage workers. In addition, mercury may penetrate a cotton mask and enter a worker's airway. Garbage workers using these inappropriate protective devices may also mistakenly believe that they are protected.

Thus, education to ensure that the correct hygiene practices are used could be an alternative to engineering controls. Behavioral factors were also associated with urinary mercury levels. From observations of work areas, contamination of hands, clothes, hand-tool and working surfaces with mercury was clearly evident at each work site. Workers who always ate snacks or drank water while working had significantly higher mercury levels than those who only did so sometimes.

Workers who always washed their hands after work ($r = -0.046$) had significantly lower mercury levels than those who sometimes did. All workers used facemasks and gloves when sorting hazardous waste from general waste. They should also use finger cots (normally latex) at work, and practice good hygiene, such as washing their hands before and after work. All of the workers who neglected to launder their clothes had significantly higher mercury levels than those who did launder their clothes. Workers normally did not change clothes before going home. These poor protective practices meant that workers were likely to carry mercury contamination elsewhere, potentially exposing their homes and families. Para-occupational or take-home exposure among workers' families may cause mercury poisoning among family members [22,23]. Acute symptoms, including headache, rash, chest tightness [14], fatigue [15], and loss of consciousness [16], were significantly higher among those with higher urinary mercury levels. The findings of the present study were similar to those of Decharats et al. [7], who studied average mercury levels in urine (median 3.30 μg/g creatinine, range 0.1-23.7 μg/g creatinine) among 45 nielloware workers, with and without acute symptoms (i.e., headache, rash, fatigue). Those who developed symptoms [20] had significantly higher urinary mercury levels than those who did not, at $p < 0.05$.

This [21] is also supported by Poulsen et al. [24], who reported adverse health effects among workers who separated domestic waste, e.g., the combustible fraction of waste (composed of paper, cardboard, and plastics), and found that workers were at increased risk of gastrointestinal symptoms, as well as irritation of the eyes and skin. However, the present study differs from Kurttio et al. [25], who studied mercury concentrations in stack emissions and median hair mercury concentrations. Elevated, but not statistically significant, levels of mercury and thioethers (compound analogous to ether, in which the oxygen has been replaced by sulfur) were found in the hair of residents in the vicinity of an incinerator in Finland. However, mercury exposure decreased as distance from the plant increased.

The present study had some limitations. The sample size was relatively small, and it was difficult to obtain cooperation. Therefore, further research in this field needs an appropriate i.e. larger sample size. Given that environmental mercury is toxic to humans, minimizing potential human exposure is advisable. This study showed that improving garbage workers' hygiene habits can reduce urinary mercury levels. Thus, personal hygiene is important, and should be stressed in education programs. In addition, employers should institute engineering controls to reduce urinary mercury levels among garbage workers.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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